IL000480

US

J1046 U.S. PTO
09/935895
08/23/01

| Europäisches Patentamt | European Patent Office | Office européen des brevets |
|---|---|---|

# Bescheinigung / Certificate / Attestation

#8
priority
Attestation
4-3002

Die angehefteten Unterlagen stimmen mit der ursprünglich eingereichten Fassung der auf dem nächsten Blatt bezeichneten europäischen Patentanmeldung überein.

The attached documents are exact copies of the European patent application described on the following page, as originally filed.

Les documents fixés à cette attestation sont conformes à la version initialement déposée de la demande de brevet européen spécifiée à la page suivante.

**Patentanmeldung Nr. / Patent application No. / Demande de brevet n°**

00202940.3

Der Präsident des Europäischen Patentamts;
Im Auftrag

For the President of the European Patent Office

Le Président de l'Office européen des brevets
p.o.

Hatten

I.L.C. HATTEN-HECKMAN

DEN HAAG, DEN
THE HAGUE, 02/04/01
LA HAYE, LE

EPA/EPO/OEB Form 1014 - 02.91

Europäisches Patentamt

European Patent Office

Office européen des brevets

# Blatt 2 der Bescheinigung
# Sheet 2 of the certificate
# Page 2 de l'attestation

Anmeldung Nr.:
Application no.: 00202940.3
Demande n°:

Anmeldetag:
Date of filing: 24/08/00
Date de dépôt:

Anmelder:
Applicant(s):
Demandeur(s):
Koninklijke Philips Electronics N.V.
5621 BA Eindhoven
NETHERLANDS

Bezeichnung der Erfindung:
Title of the invention:
Titre de l'invention:
Method of manufacturing a substantially closed core, core, and magnetic coil

In Anspruch genommene Prioriät(en) / Priority(ies) claimed / Priorité(s) revendiquée(s)

Staat:
State:
Pays:

Tag:
Date:
Date:

Aktenzeichen:
File no.
Numéro de dépôt:

Internationale Patentklassifikation:
International Patent classification:
Classification internationale des brevets:
/

Am Anmeldetag benannte Vertragstaaten:
Contracting states designated at date of filing: AT/BE/CH/CY/DE/DK/ES/FI/FR/GB/GR/IE/IT/LI/LU/MC/NL/PT/SE/~~TR~~
Etats contractants désignés lors du depôt:

Bemerkungen:
Remarks:
Remarques:

24.08.2000

Method of manufacturing a substantially closed core, core, and magnetic coil



The invention relates to a method of manufacturing a geometrically substantially closed ring-shaped core provided with a first gap which is substantially filled, which core has an inner face defining an inner circumference, an outer face defining an outer circumference and two substantially parallel side faces, and is suitable for use in a magnetic coil.

The invention also relates to a ring-shaped core which is substantially closed and provided with a first gap, which first gap is substantially filled with a spacer material, which core has an inner face defining an inner circumference, an outer face defining an outer circumference and two substantially parallel side faces, and is suitable for use in a magnetic coil.

The invention further relates to a magnetic coil comprising a core and a number of windings.

Such a core and such a method are known from an article 'The Micro-Gapped Toroid, A New Magnetic Component' by Brian Wiese and George Schaller from Ceramic Magnetics Inc, published at www.cmi-ferrite.com. Said core – hereinafter also referred to as gapped core to distinguish it from the not yet gapped, closed core - is also commercially available. In the known method a closed core is cutted into two half cores, which are subsequently glued together with a spacer material to create two gaps. The known gapped core therefore has two gaps, which together enclose an angle of 180°. The core has an outer diameter in the range of 3.4 to 12.5 mm. As follows from analysis of the known gapped core, the spacer material is a foil with a top and a bottom face. The two halves are glued on the foil, due to which on both faces adhesive is present. After assembling both halves on the foil, superfluous parts of the foil are cut away. Hence the gaps are filled with the foil material and adhesive.

A disadvantage of the known method is that the two half cores must be assembled into the gapped core. This assembly is expensive.

It is a first object of the invention to provide a method of the kind described in the opening paragraph, in which no assembly of two half cores is necessary.

It is a second object of the invention to provide a core of the kind described in the opening paragraphs, which can be manufactured in a cost-effective way.

The first object is achieved in that the method comprises the consecutive steps of providing the first gap in the core, filling of the first gap by dispensing a curable synthetic resin, and curing said curable synthetic resin.

In the method of the invention the spacer material of the first gap is not a foil, but it is the synthetic resin, which is a viscous polymeric liquid. Hence, it can be dispensed easily. This liquid is subsequently cured, which can for example be done thermally or optically with ultraviolet irradiation. Examples of curable synthetic resins are polyepoxides and polyacrylates, among others. After curing the synthetic resin has a good adhesion to the core, which is manifest by a concave surface of the synthetic resin.

In the method of the invention, an assembly of two halves of the core is not necessary. After the curable synthetic resin in the first gap has been cured, a second gap can be provided. Said second gap can be filled with a curable synthetic resin as well. Also further gaps can be provided.

The provision of the gap can be done in various ways known in the art, such as laser cutting and sawing with a diamond saw. Dispensing the synthetic resin is preferably done by using a dispenser provided with a positioning system. Such a dispenser is commercially available and known from the field of component placement machines. The method is especially, but not only, suitable for small cores, i.e. cores having an outer diameter of less than 25 mm and having a gap width less than 1.5 mm. The core preferably contains a ferrite material.

In an embodiment of the method of the invention, the core is put on a carrier having a surface before the provision of the first gap, such that the core rests with the outer face on the surface of the carrier. This embodiment of the method is very suitable for the provision of the first gap in the core. A large number of cores that are placed coaxially, can be treated – i.e. provision and filling of the first gap – as a whole, as the sawing or cutting and dispensing apparatus for the treatment is shifted coaxially. Also parallel positioned rows of coaxially placed cores can be treated at the same time using an apparatus with several cutting and dispensing means. This enlarges the capacity of manufacture substantially. The

embodiment further has the advantage that a large number of cores can be placed on the same carrier at a relatively small surface area.

In another embodiment of the method of the invention the core is attached to a carrier having a surface before the provision of the first gap, such that the core rests with said first major face on the surface of the carrier. The core is kept with at least one attachment means in its position on the surface of the carrier during the provision and the filling of the first gap. In practice a large number of cores is processed simultaneously. These cores can be advantageously placed on the carrier. Due to the attachment means, the cores keep their positions on the carrier, and – once provided - the first gaps in the cores keep their positions on the carrier. Therefore, the filling of the first gaps is simplified.

The attachment means can be chemical in character, e.g. a droplet of adhesive on the surface of the carrier or on the flat face of the core before the attachment of the core to the carrier. The attachment means can also be mechanical in character, for example a notch, a score in the surface of the carrier or one or more protrusions of the surface of said carrier. The attachment means could even be electromechanical, for example through the provision of an electromagnetic field from a source – e.g. a magnet - in or under the carrier.

In a further embodiment of the method of the invention a second gap is provided at the provision of the first gap, which first and second gap together enclose an angle of substantially 180°. If a number of cores are attached to the carrier and positioned in a line, it is easy to provide not only the first gap, but also the second gap in each of the cores; e.g. by cutting or sawing along a line. Especially if the first and the second gap are provided simultaneously, it is crucial that the attachment means keep the core – hence the two halves of the core – and the gaps of the core in their position on the surface of the carrier. It is advantageous to manufacture a core provided with a first and with a second gap; in comparison to a similar core with a first gap only, the fringing flux, and hence the electrical losses, are reduced considerably. Of course, after providing the first and a second gap further gaps can be provided.

It is an advantage of the method of the invention, that the synthetic resin can be mixed with a filler before dispensing it into the gap. Said filler can be used to adapt the properties of the spacer material in the gap, such as the magnetic permeability or the viscosity. Contrarily, in the known core the spacer material cannot be filled due to the presence of the foil. Preferably, the filler is a magnetic material. In this case the magnetic properties of the core can be adapted in an efficient way: a large number of cores with standardized dimensions and standardized gap widths can be produced, after which the

magnetic properties are fine-tuned by means of variation of the magnetic material and the concentration of the magnetic material present as filler.

The object to provide a core which can be manufactured in a cost-effective way is achieved in that the spacer material is a synthetic resin, which is substantially homogeneously distributed in the first gap and demonstrates a concave surface. As a result of the method of the invention, the core of the invention can be manufactured in a cost-effective way. An advantage of the core of the invention is that its mechanical stability is good, also if more than one gap is present or if the core has an outer diameter of about 4 mm or a thickness in the order of a millimeter. The core preferably contains a ferrite material. A gapped ferrite core has low losses, can have a small outer diameter and has a good resistance to DC saturation effects. A gapped ferrite core is therefore very well suited for use in applications with a switching frequency up to the MHz range. Cores are preferably toroidal, but can be rectangular as well, in which case the inner and outer face are constituted from several constituent faces. Their outer diameter is preferably in the range of 2 to 20 mm, and by further preference in the range of 3.4 to 12.5 mm.

In an embodiment of the core of the invention, the synthetic resin is mixed with a filler. Said filler can be any kind of solid material, such as alumina, silica, a glass, particles. An advantage of a synthetic resin mixed with a filler is that shrinkage of the synthetic resin, which takes place on curing, is limited less than 0.5 per cent, in general 0.1-0.3 per cent. Preferably the filler contains particles, which have a mean diameter of 5-50 microns. A preferred concentration of the filler is 0.1-60 volume per cent with respect to the curable synthetic resin.

In a further embodiment of the core of the invention, the filler is a magnetic material. Examples of magnetic materials are ferrites such as MnZn, NiZn, MgZn and iron-containing particles. The synthetic resin mixed with a magnetic filler has a larger magnetic permeability than an unfilled synthetic resin or air. The presence of the synthetic resin mixed with a magnetic filler has therefore a number of advantages. For example, any gapped toroidal core has a fringing flux bringing electrical loss. Due to the higher magnetic permeability, the fringing flux around the gap is reduced. Another advantage is that the core of the invention can have a gap width, which is larger than the gap width of a similar core having the same inner and outer diameter and having the same magnetic properties. For example, the gap width is enlarged from 75 to 200 micrometer, if the ratio of the magnetic permeability of the filled and the unfilled synthetic resin is about 2.7. A gap with a gap width of 200 micrometer can be manufactured more easily than a gap width of 75 micrometer.

Besides, the tolerance in the gap width of 200 micrometer is larger, thus providing higher yield. Further on, a gap having a gap width of 200 micrometer can be replaced by two gaps each having a gap width of 100 micrometer. Contrarily, a gap width of 35 micrometer comes near to a technological border of sawing or cutting.

A further advantage of the core having a first gap filled with a synthetic resin containing a magnetic filler, is that through variation of the concentration and the kind of magnetic filler, the properties of the core can be fine-tuned. At the same time, cores with fine-tuned magnetic properties can be produced in a cost-effective manner; cores can be produced with standardized dimensions and standardized gap widths. For example, the presence of a magnetic filler provides the opportunity to have in a core a gap with a gap width of 200 micrometer, which has the same magnetic permeability as an unfilled gap with a gap width of 10 micrometers.

The core of the invention can be used very well in a magnetic coil of the kind described in the opening paragraph. Said coil could be used very well in applications such as power management circuits, power invertors, signal inductors with a DC component, linear inductors and high frequency temperature stable devices.

While the invention has been described in terms of some preferred embodiments, those skilled in the art will recognize that the invention can be practiced with modification with the spirit and scope of the appended claims.

These and other aspects of the core and of the method of the invention will be further explained by means of the figures, of which:

Fig. 1 is a diagrammatic plan view of a coil with a core with a single gap according to the invention;

Fig. 2 shows schematically a cross section of the filled gap in the core, which is an enlarged detail of Fig 1 there indicated by the square I-I;

Fig. 3 shows schematically a similar cross section in detail as in Fig.2, but for the gapped core according to the prior art;

Fig. 4 is a diagrammatic perspective view of the core with two gaps according to the invention;

Fig. 5 shows schematically a perspective view of a carrier on which a number of cores are present;

Fig. 6 shows schematically a plan view of another carrier on which a number of cores are present; and

Fig. 7 shows schematically a cross-section of said carrier along the line V-V in Fig.6.

The toroidal core 1 in Fig.1 has an inner face 5 defining an inner diameter ID, an outer face 6 defining an outer diameter OD and two substantially parallel side faces 7. A first gap 2 is present in the toroidal core 1, which first gap 2 has a gap width 8. The first gap 2 is filled with a spacer material 3, that is a synthetic resin. The synthetic resin is substantially homogeneously distributed over the first gap and has a concave surface 17, as is shown in Fig. 2. Due to the synthetic resin 3 in the first gap 2 the core 1 is geometrically substantially closed. If the core 1 is used in a coil, then windings of the coil cannot leave the core 1.

The first gap 2 of the toroidal core 1 of the prior art is shown in Fig. 3. In the first gap 2 a spacer material 3 is present, which is a foil. In order to connect the foil 3 to the core 1 adhesive 4 is present. Therefore, the spacer material 3 in the core 1 of the prior art is not substantially homogeneously distributed, nor has it a concave surface.

The coil 10 in Fig. 4 comprises a toroidal core 11 and is provided with a number of windings 9. The toroidal core 11 has an outer diameter OD, an inner diameter ID, a first gap 2 and a second gap 12. The first gap 2 and the second gap 12 together enclose an angle of substantially 180 degrees. The first gap 2 and the second gap 12 have a gap width 8. The core 11 has a has a first major face 5, a second major face 6, a channel 15 running from the first 5 to the second major face 6 and a circumferential side face 7.

Fig. 5 shows a carrier 20, on which a number of toroidal cores 1 are put. The carrier 20 has a surface 21. The toroidal cores 1 are attached such that the cores 1 rest with their outer face 6 on the surface 21 of the carrier 20. In said cores 1 first gaps 2 are provided by cutting or sawing. Said first gaps 2 are subsequently filled with a curable synthetic resin by using a dispenser apparatus. After curing the curable synthetic resin, second gaps can be provided in the cores 1. This is advantageously done by rotating the cores 1 with respect to the carrier 20 in a plane perpendicular to the carrier 20.

Fig.6 shows schematically that a number of toroidal cores 11 is attached to the surface 21 of a carrier 20 with one of their side faces 7. This is done before any gaps 2, 12 are provided in the cores 11. Fig. 7 shows schematically that the cores 11 are kept with attachment means 22, 23 in their positions on the surface 21. The attachment means 22 is a

protrusion, which keeps the cores 11 in their positions mechanically. The attachment means 23 is a droplet of adhesive, with which the cores 11 are kept in their positions chemically. While kept in their positions first gaps 2 and preferably second gaps 12 as well can be provided in the cores 11 and filled with a curable synthetic resin. The choice of attachment means 22, 23 is open to other embodiments. With a suitable design of the protrusions 22 a third and a fourth gap can be provided and filled after a rotation of the carrier of 90 degrees with respect to – not shown – sawing and dispensing apparatus. Said rotation is to be done in the plane of the surface 21 of the carrier 20.

EXAMPLE 1

A MnZn-ferrite based toroidal core 1 with OD = 4.5 mm, ID = 2.3 mm and height = 1.4 mm has a first gap 2 with a gap width 8 of 50 μm. The core 1 has a permeability of 2000, due to which an inductance of $45.10^{-9}$ H/$n^2$ is generated when applying the core 1 in a magnetic coil 10. In the said expression n is the number of windings 9. The first gap 2 is provided by sawing with a diamond blade. The first gap 2 is filled with a UV-curable, adhesive synthetic resin without any inorganic filling material. The synthetic resin has a viscosity of 200 mPa.s. Initial curing is achieved by UV spot exposure at an intensity of 2000 mW/$cm^2$ during 2 seconds. The optimal thermal properties of the synthetic resin are achieved via a post-curing step. In order to fulfil isolation requirements for toroidal cores 1, the core 1 is completely coated with an organic material.

EXAMPLE 2

Before filling the first gap 2 the UV-curable, adhesive synthetic resin is mixed with a filler. The filler substantially consists of MnZn-based ferrite particles with a size of 10-30 μm. The synthetic resin is mixed with the filler at a filler concentration of 65 wt%. The filled synthetic resin has a viscosity of 1500 mPa.s. The filled synthetic resin has a permeability of about 10.

In the MnZn-ferrite based toroidal core 1 with an OD of 4.5 mm, an ID of 2.3 mm and a height of 1.4 mm is a first gap 2 provided. The first gap 2 has a gap width of 370 μm. The gap is filled with the filled synthetic resin by dispensing. Subsequently the gap is initially cured by UV-spot exposure followed by thermal curing for 3 minutes at 150-200 °C. In order to fulfil isolation requirements for toroidal cores 1, the core 1 is completely coated with an organic material. When applied in a magnetic coil 10, the core 1 provided with a first

gap 2 filled with a synthetic resin mixed with ferrite particles has an inductance of $30.10^{-9}$ $H/n^2$, in which n is the number of windings 9.

EXAMPLE 3

A MnZn-ferrite based toroidal core 11 has an OD of 9.4 mm, an ID of 5.1 mm and a height of 2.6 mm. The core 11 has a first gap 2 and a second gap 12, each of which gaps has a gap width 8 of 200 µm. The core 11 has a permeability of 2000, due to which an inductance of $25.10^{-9}$ $H/n^2$ is generated, when the core 11 is applied in a magnetic coil 10. In the said expression n is the number of windings 9. The first gap 2 and second gap 12 together enclose an angle of substantially 180 degrees. The core 11 is manufactured by clamping the core 11 with its flat face 6 on the surface 21 of a carrier 20, followed by sawing with a diamond blade, dispensing a UV-curable synthetic resin in the first gap 2 and the second gap 12 and curing. The synthetic resin has a viscosity of 600 mPa.s, as it is mixed with a filler of $Al_2O_3$ in a concentration of about 40 weight per cent. In this way the original gap size dimensions are maintained. Initial curing is done by a UV spot exposure at an intensity of 2000 $mW/cm^2$ during 2 seconds. The optimal thermal properties of the adhesive are achieved via a post-curing step. In order to fulfil isolation requirements for toroidal cores 1, the core 1 is completely coated with an organic material.

CLAIMS:



1. A method of manufacturing a geometrically substantially closed ring-shaped core (1) provided with a first gap (2) which is substantially filled, which core (1) has an inner face (5) defining an inner circumference, an outer face (6) defining an outer circumference and two substantially parallel side faces (7), and is suitable for use in a magnetic coil (10), which method comprises the following consecutive steps:

- providing of the first gap (2) in the core (1),
- filling of the first gap (2) by dispensing a curable synthetic resin, and
- curing said curable synthetic resin.

2. A method as claimed in claim 1, characterized in that before the provision of the first gap (2) the core (1) is put on a carrier (20) having a surface (21), such that the core (1) rests on the surface (21) of the carrier (20) with said outer face (6).

3. A method as claimed in claim 1, characterized in that

- before the provision of the first gap (2) the core (1,11) is attached to a carrier (20) having a surface (21), such that the core (1) rests with one of its side faces (7) on the surface (21) of the carrier (20), and
- the core (1) is kept with at least one attachment means (22;23) in its position on the surface (21) of the carrier (20) during the provision and the filling of the first gap (2).

4. A method as claimed in claim 3, characterized in that with the provision of the first gap (2) a second gap (12) is provided, which second gap (12) is diametrically opposed to the first gap(2).

5. A method as claimed in claim 1, 2 or 3, characterized in that before dispensing the curable synthetic resin, a filler is added to the synthetic resin.

6. A ring-shaped core (1,11) which is substantially closed and provided with a first gap (2), which first gap (2) is substantially filled with a spacer material, which core

(1,11) has an inner face (5) defining an inner circumference, an outer face (6) defining an outer circumference and two substantially parallel side faces (7), and is suitable for use in a magnetic coil (10),
characterized in that the spacer material is a synthetic resin (3), which is substantially homogeneously distributed in the first gap (2) and demonstrates a concave surface (17).

7. A core (1,11) as claimed in claim 6, characterized in that the synthetic resin comprises a filler.

8. A core (1,11) as claimed in claim 7, characterized in that the filler is a magnetic material.

9. A core (1,11) as claimed in claim 6 or 8, characterized in the core (1,11) comprises a second gap (12), and that the first (2) and the second gap (12) together enclose an angle between 5 and 355°.

10. A magnetic coil (10) comprising a core (1,11) as claimed in claim 6 and a number of windings (9).

ABSTRACT:

A core (1) for use in a magnetic coil with a filled first gap (2) is provided by the provision of the first gap (2), filling the first gap (2) with a curable synthetic resin (3) and curing said resin (3). After curing, the synthetic resin is substantially homogeneously distributed over the first gap (2) and has a concave surface (17). The synthetic resin (3) can contain a filler, which preferably substantially consists of a magnetic material.

Fig. 1

EPO - DG 1

25. 08. 2000

41



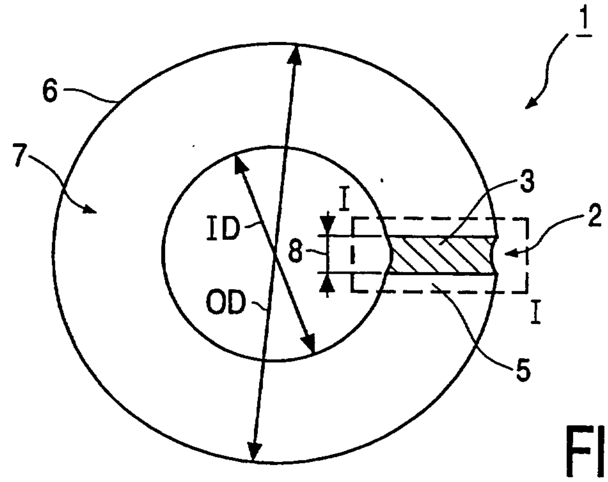


FIG. 1

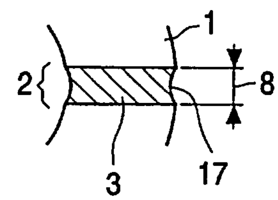


FIG. 2

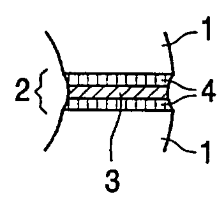


FIG. 3

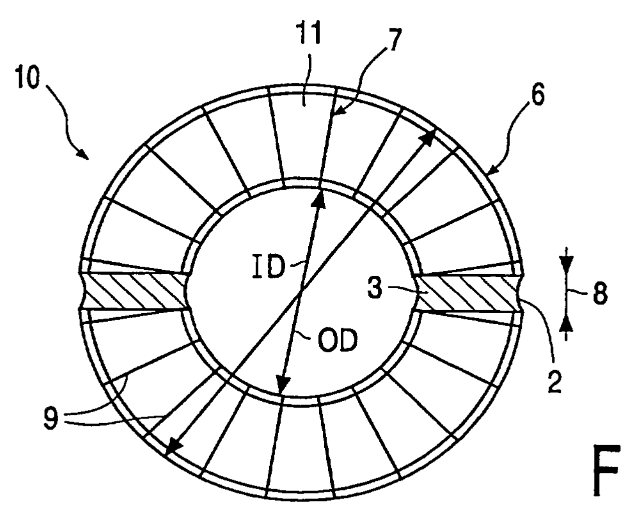


FIG. 4

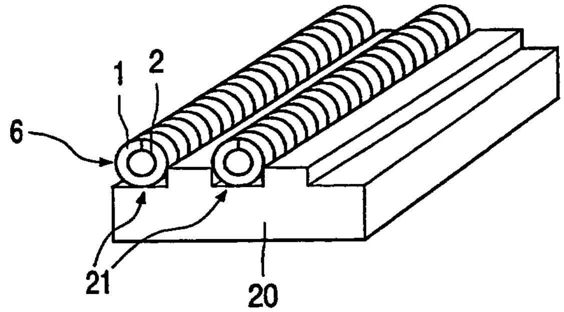


FIG. 5

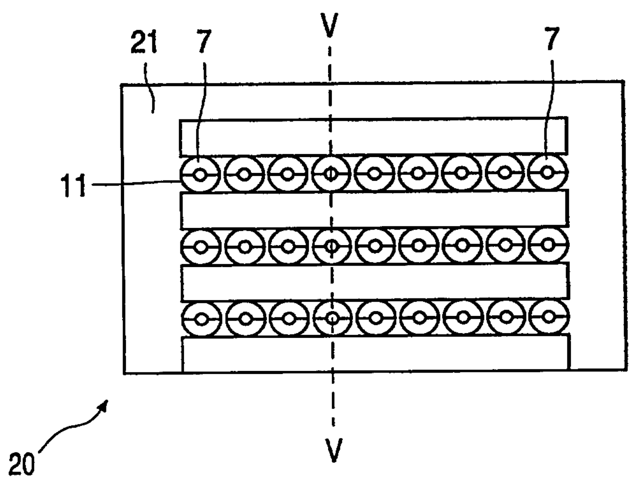


FIG. 6

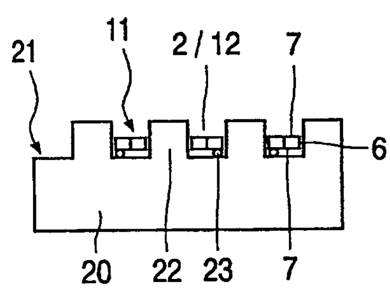


FIG. 7